X.—*Photography in connection with the Observation of the Transit of Venus at Roorkee, December 9th (Civil)*, 1874.—*By Captain* J. Waterhouse, *Assistant Surveyor General of India.*

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In December last I communicated to the Society a brief account of the proposed arrangements for observing the Transit of Venus at Roorkee, drawn up by Capt. W. M. Campbell, R. E., and although the popular interest in the subject has now somewhat worn off, a description of the operations connected with the application of photography to the observation in India of this very important astronomical event may not be without interest to the members of the Society, and as a record of experience gained, be useful on a future occasion.

*Object of Photographic Observations.*—Without entering into the consideration of the astronomical problems involved, it may be briefly stated that the object in view in making photographic observations of the Transit of Venus was to obtain a series of images showing, with the utmost attainable accuracy, the exact relative positions of the planet and the sun at carefully noted times during the progress of the Transit at the different stations of observation; so that by combining these photographs, the path of the planet across the solar disc might be accurately determined and the solar parallax be estimated by comparing the paths thus deduced for different stations. It was further proposed to endeavour to secure a graphic time-record of the exact moments at which the internal contacts of the planet and the limb of the sun took place, by means of an arrangement enabling a large number of photographic pictures to be taken on a single plate at intervals of a second or so just about the time of contact. It was anticipated that results of the highest possible value and reliability would be obtained if photographs sufficiently exact to allow of minute micrometrical measurement could be secured, as such photographs would form a permanent and indisputable record, entirely free from the errors and imperfections inseparable from personal observation, and have the further advantage that they might be examined at leisure and, if necessary, carefully compared by several independent examiners. How far these anticipations have been fulfilled still remains to be seen; but as several hundred photographs have been obtained in various parts of the world by different photographic processes and with dissimilar instruments, sufficient data will probably have been gained to test the value of photography for observations of so delicate a nature and, if this is satisfactorily proved, to show by what methods it may most successfully be applied.

The superintendence of the official arrangements for the observation of the Transit in Northern India was entrusted to Colonel Tennant, R. E., who has done so much to further the progress of astronomy and solar physics in this country, and was one of the first to recognise the value of photography as a means of recording the Transit. He selected Roorkee in the N. W. Provinces as his station of observation, partly on account of the great advantages to be gained by the proximity of the Canal Workshops for setting up the observatory and the repair and adjustment of instruments.

*Photoheliograph.*—It was arranged that photographic observations should form part of Colonel Tennant's programme and that with this object he should be furnished with a photoheliograph by Dallmeyer, of the same construction as those supplied to the English and Russian expeditions. These instruments were on the same principle as the photoheliograph designed by Dr. Warren De la Rue for the Kew Observatory, and consisted of a telescope combined with a photographic camera, equatorially mounted, and driven by clockwork. According to a description given by the maker, the object glass was 4 in. diameter and 60 in. focal length, corrected to combine the chemical and visual foci. The image of the sun formed at the principal focus was about $\frac{1}{2}$ in. in diameter and was thrown on to an enlarging combination by which an enlarged image about 4 in. diameter was projected on to the sensitive photographic plate arranged as in an ordinary camera. A little in front of the enlarging lens was a slide pierced with two circular openings, one fitted with spider-web crosslines and the other with a glass plate ruled with a fine reticule of squares, and capable of adjustment so as to be brought into the focus of the object-glass in order that the cross-wires and reticule might be enlarged and brought to fine focus at the same time as the image of the sun. The pictures could thus be taken with the cross-wires, which served as a reference mark for measurements in connection with the declination and right ascension circles, or with the reticule, by means of which any optical distortion caused by the secondary enlargement of the image could be measured.

The quick exposure of the plates was effected by means of a shutter sliding between the cross-wires and the enlarging lens, in which position the object could be effected with a minimum of motion. This shutter was held at its lower end by a spring and was arranged so that when raised to its full extent, by means of a string attached to its upper end, the passage of the solar rays to the sensitive plate was cut off. This string passed over a pulley on the body of the instrument and had at the end a hook on which a loop of strong cotton thread was attached and, being stretched so as to pass over a conical block fixed on the camera, retained the shutter in its raised position. When the thread was cut, the force of the spring imme-

diately drew down the shutter and allowed a momentary exposure of the sensitive plate to the solar rays during the passage of a slit in the shutter, the width of which could be increased or diminished at will from nil to ·5 of an inch by means of another slide worked by a screw connected with a graduated scale. The rapidity of motion of the shutter could also be regulated by increasing or diminishing the tension of the spring by means of a screw.

When the shutter was down the solar rays were quite cut off; but by a simple arrangement a circular aperture above the exposing slot could be brought into a position concentric with the axis of the telescope, thus permitting the whole bundle of rays to pass uninterruptedly through the camera and enabling the image to be examined for focussing, &c.

The camera of the photoheliograph was constructed to take plates six inches square. The position of the image on the plates was regulated by means of a finder fixed on the outside of the telescope tube and consisting of a lens throwing an image of the sun upon a screen made of talc covered with paper, and adjusted so that when the enlarged image was in its proper position on the ground glass of the camera the finder image just filled a square ruled on the talc screen.*

*Janssen Slide.*—A repeating arrangement for taking several pictures on one plate, designed by Dr. Warren De la Rue on the principle proposed by the eminent French astronomer M. Janssen, and known as the Janssen slide, also formed part of the equipment. This arrangement having been fully described and figured by Dr. De la Rue,† it will suffice to say that it consists of a circular wooden case about 12 in. in diameter and 2 in. deep, with a removable shutter in front and constructed so as to be fitted on to the camera in the position occupied by an ordinary dark slide. Revolving on a central axis within this case is a metal disc or plate-holder, with 60 radial slots and as many circular spaces racked in its edge, carrying the sensitive plate held between rings strongly electroplated with silver. Outside the case, in front, a second smaller disc revolves just outside the shutter and is provided with a radial opening capable of being opened or closed at pleasure, so as to regulate the exposure by admitting more or less light to the plate through a radial slit cut in the shutter of the slide, about 1 in. long and exactly corresponding in position and width to the sixtieth part of the circumference of the plate. The axis of this exposing disc passes through the case and carries a pin which fits into the slots in the edge of the revolving plate-holder and is turned, from outside the case, by means of a winch arranged with gearing, so that it may be

* The screen originally supplied with the instrument was of parchment, but as this was found to expand and contract with the variations of moisture in the air, it was advantageously replaced by the talc and paper screen.

† Roy. Ast. Soc. Monthly Notices, May 1874.

worked either by hand or automatically by means of clockwork. This axis also carries an ivory ring on the periphery of which is fixed a piece of platinum wire which, as the axis revolves, comes into contact with a strip of platinum fixed on a spring attached to a connector, so that it may be placed in electrical communication with a chronograph and electric clock and thus enable the precise moment to be recorded, when the uncovering of the aperture in the shutter of the slide by the exposing disc exposes a portion of the plate to the sun. As there are sixty slots and the aperture corresponds to the sixtieth part of the circumference of the plate, it is evident that for each entire revolution of the plate-holder sixty distinct images will be impressed on as many separate portions of the plate within an annular space about 1 in. wide round its circumference.

The apparatus is constructed so that the plane of the sensitive collodion film shall exactly coincide with that of the focussing screen of the camera, and in order to adjust the instrument so as to obtain an image of any desired portion of the solar limb or disc, it is arranged that when the sensitive plate is in the proper position for receiving the first image of the sixty, the observer can look from behind, through a series of three red glasses, one of which is in front of the plate, on the exposing disc, and the other two behind it, one on the revolving plate-holder and the other on the wooden case. The three glasses are coincident only in one position, *i. e.*, when the stop, formed by racking the last of the radial slots for only a short distance, is on the right of the axis ; and as the stop is on the left of the axis after a complete revolution, the revolving plate-holder must always be reversed through an entire revolution after each operation in order to bring it into the proper position for focussing. While focussing, the sensitive plate itself acts as a focussing screen.

By means of clockwork the rate of revolution of the plate-holder could be so adjusted that the exposures might be made at intervals varying from about half a second to two seconds, but as it was desirable not to expose the separate pictures too rapidly, the rate was set so that the entire revolution might be accomplished in about a minute and a half.

*Preliminary trials with Dry Plates.*—I received intimation about the middle of August 1874 that, with the concurrence of the Surveyor General, my services were likely to be placed at Colonel Tennant's disposal for the superintendence of the photographic observations. As there appeared to be a general opinion in Europe that a dry process would be most suitable for continuous observations lasting over a period of some hours and would have other special advantages for the purpose, the first thing to be done was to select the process to be used and to gain some experience in working it ; and although the weather at that time of the year was most unfavorable to photography and very trying to work in, all the time that could be

spared from my regular office duties was devoted to preliminary trials of dry plates in Calcutta till October, when I joined Colonel Tennant at Roorkee.

It was understood that the English observers were to use the beer-albumen dry process recommended by Captain Abney, R. E., and therefore my first trials were with it; but although the instructions given by Captain Abney were carefully carried out, it was found impossible to obtain the exalted sensitiveness claimed for the plates and, though the pictures obtained had many good qualities, the exposures were so long that I could not but consider the process unsuitable and look for some other by which more sensitive plates could be secured. The beer-albumen process was, however, tried on several different occasions, both in Calcutta and at Roorkee, with different collodions and various samples of beer, but always with the same result.

The cause of the great want of sensitiveness shewn by these plates could not be discovered. Captain Abney says that those who have not succeeded with his process have not used a sufficiently porous collodion ; but on this occasion several collodions were used, some containing a large proportion of water, but without any noticeable advantage ; though other dry plates taken with the same collodions gave much greater sensitiveness.*

It is possible that the beer used was not quite suitable from containing too large a quantity of chlorides or other substances detrimental to sensitiveness, and that this was probably the case is shown by the fact that a much greater sensitiveness and generally better results were obtained with the mode of working the beer-albumen process recommended by Mr. Davies of Edinburgh, in which a small quantity of nitrate of silver is added to the beer with the effect of throwing down all the chlorides and much of a glutinous substance; but even this modification did not give quite satisfactory results and the idea of using the beer-albumen process for the Transit plates was given up. Although the process has no doubt yielded excellent results in the skilled hands of Captain Abney and others, the uncertain composition of the different liquids known as beer render it undesirable that this substance should be used in the preparation of dry plates which are to serve as a standard for scientific purposes and from which comparable results are expected. For such purposes more certainty and

* I have quite recently tried the beer-albumen process again with samples of collodion yielding good results with other dry processes—but found the plates just as insensitive as they were before. By flowing the films, after washing away the free silver, with a 10-grain solution of pyrogallic acid in beer, then again well washing, and finally flowing the plate with a mixture of glycerine and dilute albumen, plates were obtained giving excellent results with at least ten times more sensitiveness than those prepared by Captain Abney's plan.

uniformity will be attained by the use of materials which are likely to be of nearly the same chemical composition in all parts of the world.

As the beer-albumen process was not found to answer, attention was turned to other dry processes and several different methods were tried with varying results.

At an early stage of the experiments it was found from trials with a rough photoheliograph, constructed in Calcutta for the purpose, that a process which might give very good results for taking views &c. would not answer for the sun and *vice versâ;* and the same was afterwards found to be the case when working with the English photoheliograph.

Among the most promising dry processes tried in these preliminary experiments were the gum-gallic, in which the so-called preservative is composed of a solution of gum arabic and gallic acid, and a process in which the preservative was laudanum, either alone, as a dilute solution in water containing from 16 to 4 per cent. of laudanum, or mixed with gum arabic or gum tragacanth, in order to keep the pictures free from the stains liable to occur when using the laudanum alone. Excellent results for views were also obtained with a filtered mixture of laudanum and very thin arrowroot water. I was induced to use the laudanum from a statement of Prof. Vogel of Berlin, that plates prepared with morphia were more sensitive to the comparatively nonactinic rays from the outer part of the solar disc; and though I did not remark any special superiority in this respect, the laudanum plates were found more sensitive than most of the others tried. Plates prepared with a saturated solution of morphia in water also gave good results.

The addition of nitrate of uranium to the nitrate of silver bath used for sensitising the plates, as recommended by Captain Abney, was found advantageous for most of the dry plates, giving increased sensitiveness and other good qualities. As some doubt has lately been thrown on the advantage of the uranium bath, it may be as well to state that in the ordinary wet process with bromo-iodised collodion I have found that no advantage is gained by the addition of the uranium salt to the nitrate bath, but, on the contrary, there is a great loss of sensitiveness. With dry plates, however, it is different, the gain in sensitiveness is well-marked and the shadows appear cleaner than on plates sensitised in the ordinary bath without the uranium.

*Shrinkage of the Collodion films.*—When it was first proposed to employ photography in observing the Transit, it was objected that the collodion processes would be unsuitable on account of the shrinkage or contraction the collodion films undergo in drying. De la Rue in 1861 made some very careful experiments, the result of which was to shew that with proper precautions the shrinkage was entirely in the thickness of

the collodion film: more recently, however, Paschen had found this contraction to amount to not less than $\frac{1}{18\frac{1}{56}}$ of the length of the plate with albumenised plates, and to $\frac{1}{21\frac{1}{28}}$ of unalbumenised plates; in one instance it being so much as $\frac{1}{5\frac{1}{23}}$ of the length and $\frac{1}{6\frac{1}{18}}$ of the breadth of the albumenised plate. Rutherfurd, on the other hand, found that if the plates received a preliminary coating of albumen, the shrinkage of the wet film in drying did not exceed $\frac{1}{4\frac{1}{8\,0\,0}}''$ and was, on an average, about five times less. Prof. H. Vogel, of Berlin, also made some experiments on the conditions affecting the stability of the collodion film, which proved the value of a substratum as a preventive of contraction of the film and shewed that dry plates were less liable to contraction than wet. Captain Abney and Colonel Stuart Wortley, when experimenting on a dry process to be used for the transit by the English expeditions, also gave this subject their careful consideration and came to the conclusion that with proper precautions the amount of shrinkage would be so small as to be negligible. Notwithstanding this concurrence of testimony as to the possibility of disregarding the contraction of the film, I thought it desirable to satisfy myself as to the suitability in this respect of the various dry processes I was trying, and the plates were therefore tested by a method which I afterwards found was somewhat similar to that followed by Dr. De la Rue, and appeared to have the advantage of entirely avoiding any chance of error from parallax caused by want of absolute contact between the test lines and the collodion film. Several glass plates five inches square were prepared by drawing on them, with a very fine diamond point, diagonal lines through the corners of the plates. With the intersection of the diagonals as a centre, a circle was described 4 in. in diameter, so that it might correspond in size with the solar disc on the plates to be taken during the Transit. These test plates were then coated with the usual albumen substratum and prepared exactly in the same way as the dry plates under trial. They were exposed to light from the back, so that an impression of the engraved lines was obtained through the film. The plates were then developed in the same way as the other plates and when dry, examined under a very powerful micrometer capable of dividing to the $\frac{1}{1\,9\,0\,0\,0\,0}$ of an inch. To facilitate the examination, a piece of the film was cut away across the lines in different parts of the plate, and the course of the uncovered part of the line compared with the covered part. In no case was any perceptible difference found, except when the substratum had been purposely omitted, or processes used which gave rise to blistering of the film. The only chance of error I could see in this plan was the sticking of the film to the rough surface of the engraved lines; but in the cases where the film blistered it was found that the blistering was more marked on the lines than elsewhere, and so it would appear that the lines did not exert any particular influence on the free motion of the film. I had not

time to go into the subject very thoroughly nor the means of trying other tests.

*Arrangements of the Observatory.*—I arrived at Roorkee on the 13th October and thus had about eight weeks for preparation. Colonel Tennant had built an observatory with domes for all the observing instruments and had allotted to me a very convenient dark room about ten feet square, attached to the dome in which the photoheliograph had been erected and separated from it by a narrow passage about 7 feet long and 3 feet wide. I had doors placed at each end of this passage, so that communication could pass between the dome and the dark room without letting light into the latter; and in order to avoid the necessity of constantly opening the doors for the passage of the dark slides to and fro, a sort of box opening at both ends and large enough to hold a dark slide was let into the panelling of each of the doors, and the dark slides were thus easily passed backwards and forwards without any risk of letting in light or raising of dust. Double doors were also constructed at the entrance to provide for communication from outside without interruption of the work going on within. Tables and shelves were arranged in the dark room so as to keep all the operations and the necessary chemicals and appliances for each quite distinct; thus there was a table for the nitrate baths and near it, shelves for the collodions and plate boxes. Another table with sink, was set apart for developing and close by, were shelves for the developers and chemicals &c. used for developing. A third table was used for changing dry plates and above it were shelves for the dry plate boxes. Some such system was absolutely necessary in such important operations, and the principle of a place for every thing and every thing in its place was rigidly adhered to.

As it was undesirable to use the dark room in the observatory for the preparation of plates and chemicals or as a store room, nothing was kept in it except the chemicals and apparatus actually required there. A dark room for the preparation of dry plates, testing baths, &c., was fitted up in a house immediately opposite the observatory, and here also all mixing of chemicals, cleaning plates, and other preparatory work was carried on and spare stores kept.

The photoheliograph had been erected by Colonel Tennant before my arrival on an isolated brick pillar in the centre of a circular room 12 feet in diameter, fitted with a revolving observatory dome.

It was arranged that the times at which the several photographs were exposed should be recorded by electricity on a chronograph placed in an adjoining room in electric communication with the standard clock, which also gave the time to a clock-dial placed in the dome.

This was effected by the use of a tappet or make-circuit key, to which Colonel Tennant had very ingeniously fitted a pair of scissors so that the act of cutting the thread to let loose the exposing shutter of the photoheliograph, completed the circuit and the exact time of exposure was thus instantaneously recorded on the chronograph. The Janssen slide was also fitted with arrangements for being placed in electric communication with the chronograph, so that every turn of the winch was recorded at the moment of exposing each picture round the circumference of the plate.

The staff of assistants at my disposal included three European assistant-photographers, Sergeant J. Harrold, R. E., of the Photographic Branch Surveyor General's Office, Calcutta, Lance-Corporal George and Private Fox, of H. M.'s 55th Regiment, who had been thoroughly trained by Colonel Tennant in the ordinary manipulations of the wet collodion process, with three native servants for handing the plates to and fro and performing other menial duties.

*Preparatory Work and Drills.*—One of the first things to be done before beginning the drills was to examine the whole stock of glass and carefully select about 200 of the best and most free from flaws, which were carefully set aside to be used for the Transit.

The dry plate trials were resumed with the advantage of having a suitable instrument to work with. The beer-albumen and other processes that had been found more promising in Calcutta were tried again, but were found not quite satisfactory with the sun; the tea and coffee processes, which I had not tried in Calcutta, were better and I finally adopted a modification of the coffee process recommended by M. Constant of Lausaune, substituting albumen for gum to avoid the tendency to blistering so common when using gum, and also with the view of lessening photographic irradiation, against which the coffee proved a further protection. These plates were easily prepared and were found fairly sensitive, easily intensified, perfectly clear and free from blurring in the shadows.

The glass plates, having received a thin coating of albumen as a substratum, were coated with collodion and sensitised by a somewhat prolonged immersion in a 40-grain silver bath, then washed in four changes of distilled water and finally immersed in a resensitising solution, or so-called preservative, composed of

| | |
|---|---|
| Dried albumen ..... | 2 grammes |
| Sugar ..... | 12 „ |
| Coffee infusion made by boiling 30 grammes of coffee in 360 C. C. of water ..... | 300 cub. cents. |
| Water..... | 300 „ „ |

and then drained and dried without heat.

As soon as arrangements were sufficiently advanced, preliminary drills were commenced with the object of finding out the best mode of working, in the event of dry plates being used, and after a few trials, it was arranged that instead of developing every twelfth dry plate, as proposed by the English observers, every fifth plate should be prepared by the wet process and developed at once to ascertain if all the adjustments were correct, the necessary alterations in the exposure of the plates being arranged by trials beforehand.

From some cause all the dry plates prepared at Roorkee were covered with spots, some transparent, others opaque and comet-like, and as it was impossible to trace the cause of these spots or to avoid them, even with the most careful precautions, trials were made, about the 17th November, to ascertain if the ordinary wet process could be used instead and, after working a few days, it was found that there was no difficulty in keeping a regular supply of plates every two minutes by the use of four sensitising baths. The superior convenience of working by the wet-plate system and the great saving of time and trouble that would be gained became so manifest that it was definitely decided to adopt it and thenceforth the wet plate drills were carried on daily between the hours of 7 and 12, during which the Transit would take place; as a rule in the early morning and forenoon, alternately, sometimes twice during the same day. Particular attention was given to practising the mounting of the Janssen slide by signal and again unmounting it and resuming the ordinary plates in the interval.

Although the use of dry plates was said to possess the great advantage of enabling irradiation to be much diminished by the use of albumen in the re-sensitizer and also in reducing the shrinkage of the film to a mininum; as well as great convenience in preparing and developing the plates at leisure free from excitement or hurry, and in facilitating the working of a large number of plates with a small staff of assistants, the substitution of the wet process had many advantages in avoiding the very tedious operations of preparing and developing so large a number of plates, which alone would have taken up about two days before and after the Transit, and more particularly in enabling the state of the work to be seen throughout the Transit and any necessary alterations to be carried out immediately. The manipulations of the wet process were perfectly familiar to all my assistants and by a division of labour they were able to carry on the work with ease and without the slightest confusion.

By giving the films a substratum I hoped to avoid any shrinkage of the collodion in drying and by placing pieces of wet red blotting paper behind the plates to lessen the tendency to irradiation.

My programme of operations having been drawn up and approved by Colonel Tennant, the first rehearsal took place on the 28th November with tolerable success, and several points were noticed as requiring modification.

After further practice, a second full rehearsal took place on the 2nd December, and a final one on the 6th, which was very successful; 120 six-inch plates with 6 Janssens being exposed in the course of the time the Transit was calculated to last.

The preparations for the Transit itself, such as numbering and cleaning glasses, preparing and testing baths, and examining the minor adjustments of the instruments were commenced about a week beforehand.

Unfortunately the weather for a few days before the Transit was very cloudy and most unfavorable for trials of chemicals and testing the focal adjustments of the instrument, which caused some trouble and uncertainty.

Although it was determined to adopt the wet process entirely for the Transit plates it was considered desirable to have a small supply of dry plates prepared in reserve in case of accidents and to be used, if necessary, at times when the supply of wet plates could not readily be kept up. About a dozen of the six-inch and four of the Janssen plates were therefore prepared by the coffee-albumen process, already described, using a highly bromized collodion recommended by Captain Abney for sun pictures, which gave an intense picture with considerable sensitiveness; but owing to the short time between receiving the materials from England and their being used this collodion had scarcely time to ripen properly, and so could not have a fair trial. Captain Abney's formula was—

| | | |
|---|---|---|
| Thomas' bromized collodion | 20 | oz. |
| „ iodized „ | 20 | „ |
| Alcohol s. g., 805 | 6 to 8 | „ |
| Pyroxyline | 300 | grs. |
| Water | 120 | min. |

The plates were developed with the strong alkaline developer recommended by Captain Abney.

One of these Janssen plates and four of the six-inch plates were used during the Transit and, with the exception of the spots, were excellent pictures, fairly sharp and dense, free from blurring, and, in some respects, better than many of the wet plates.

Several days before the Transit 120 six-inch glasses were selected from those set aside as the best and were numbered with a diamond in one corner consecutively from 1 to 120. A reserve of about 30 plates was also selected and marked with a cross in one corner. The whole of these plates as well as a dozen of the best circular Janssen plates were then carefully cleaned and coated, on the unmarked side, with an albumen substratum, consisting of the white of one egg and about one drachm of ammonia to a wine-bottle of water, in order to prevent any rising of the film and consequent liability to shrinkage. The plates thus numbered and albumenised were arranged in order in five boxes, hold-

ing two dozen each, with the marked corners running along the upper left hand side of the boxes. Each box was then legibly marked with a distinguishing letter and the numbers of the plates contained in it thus $\frac{A}{1\text{-}24}$. A sixth box containing marked plates was kept in reserve to be used if required, and it was arranged that any plates so used were to be numbered at the time of use with their proper number in order of sequence.

It was also carefully enjoined on the assistants that the utmost care was to be taken to preserve the proper order of sequence of the plates throughout the operations, but that if, by accident, a plate should be left out or any alteration in sequence occur, the officer in charge should be at once informed of it and duly record it. Should any of the plates originally numbered be broken during any of the operations or put aside from any other cause, their places were to be filled up from the marked plates and they were to be numbered in their proper order of sequence.

Arrangements were made for providing four nitrate of silver baths of suitable size for sensitising the six-inch plates and a larger one for the Janssen plates; besides these, two small baths and one large one were kept ready in reserve in case of one of the other baths getting out of order or becoming temporarily unfit for use. The baths used were new and about 45 grains to the ounce (10·2 per cent.).

The collodion used was prepared according to a formula given me by Colonel Tennant as follows:—

| | | |
|---|---|---|
| Cadmium Iodide, | 1 | gramme. |
| Cadmium Bromide, | 1 | „ |
| Ammonium Iodide, | 1 | „ |
| Pyroxyline, | 4 | „ |
| Ether, | 110 | cub. cents. |
| Alcohol, | 110 | „ „ |

This collodion contained a large proportion of pyroxyline and haloid salts and was selected because it was found to give more density of the film and intensity of image than the ordinary commercial samples. Two pints of it were carefully cleared for use during the Transit.

A reserve supply of a mixture of Thomas' and Rouch's was also used for some of the plates. It was arranged that the collodion should only be used once, so that each plate might be coated with fresh collodion, thus preserving the uniformity of the films and keeping the collodion free from impurities.

An ample supply of developer was also prepared by the following formula:—

| | | |
|---|---|---|
| Protosulphate of Iron | 55 | grammes |
| Sugar | 55 | „ |

| | | |
|---|---|---|
| Glacial Acetic acid | 40 | cub. cents. |
| Spirits of Wine | 30 | „ „ |
| Water | 1000 | „ „ |

A solution of cyanide of potassium was used for fixing.

It was considered advisable not to intensify the plates, but to obtain the greatest possible intensity from the first development.

As the plates were developed they were placed in a draining rack in order as taken and put aside till after the Transit.

The distribution of duties was arranged as follows:—

I remained at the Photoheliograph to expose the plates at every two minutes and record the times of exposing each plate by the clock dial, which had previously been ascertained to agree with the standard clock, carefully noting any variation in the intervals and any other noteworthy circumstance connected with any of the plates. At every sixth plate, with a few exceptions, the cross-wires were replaced by the reticule.

Sergt. Harrold developed the plates and generally supervised the operations in the dark-room. He was directed to take special care that the plates were arranged in the racks in their proper order of sequence as developed, and to note in writing any variations. He was at once to inform me of any defects in exposure or in the position of the image on the plate.

Corporal George coated the plates with collodion and sensitised them. He was responsible that the plates were taken in the proper order, as numbered and arranged in the boxes, and was ordered to at once report any change. In case of having to pass over any of the marked and numbered plates, he was to properly number the plates substituted for them. In order that the position of the sun's image might be the same on all the plates, he was ordered when coating the plates with collodion to keep the unnumbered side of the plate uppermost, with the numbered corner away from him on his right hand, pouring off the collodion at the near right-hand corner.

Private Fox took the plates out of the baths and placed them in the slide so that the numbers might be at the upper left-hand corner of the slides and the thick collodion at the lower left-hand corner. (This arrangement of the plates when being coated and placed in the slides was observed throughout all drills and practice plates, and answered the purpose perfectly.) He then placed the dark slides in the receptacle in the door from which they were passed into the dome by the man in the passage between the doors. It was also his duty to carry the Janssen slide into the dome, place on and take off the No. 1 counterpoise, which was fixed at the end of the declination axis, and carry the Janssen plates back again for development. In case of there being any delay in a wet plate being ready at the proper time, he was to keep a dry plate in readiness to be sent in instead, notify-

ing the change, and this he was ordered to do at all changes from wet to dry and *vice versâ*.

In order to prevent mistakes and confusion in communicating between the dome and the dark room, it was arranged that all communications should be in writing; supplies of slips of paper with a pencil attached were kept in a convenient position in different parts of the dark room and the dome, and were passed to and fro through the slides in the doors without noise or disturbance of the operations.

Of the three native servants, one remained in the dark room to hand the dark slides backwards and forwards, but when the Janssen slide was used he went into the dome to put on the No. 2 counterpoise, at the object glass end of the telescope; another man remained in the space between the double doors and passed the dark slides in and out through the slides in the doors. The third stood in the dome to hand me the dark slides, hold the loops of thread and hook them on the string attached to the exposing shutter, turn the dome, and give me any other assistance I required.

Corporal George and Private Fox took it in turns to act as orderly of the week and their duties were to open the dome for work, have the water boxes filled at the proper times, uncover the instrument, see that the necessary chemicals and glasses were ready in their places for use, and after work, to have the rooms cleaned, the instrument dusted, and the dome closed.

Two or three days before the Transit I examined all the adjustments of the sliding shutters and the electrical communications and satisfied myself that all were in good order.

As the weather had been cloudy two or three days before the Transit there was some uncertainty as to whether it would be fine or not, but, in the event of its turning out cloudy, I had arranged that the whole operations were to be gone through just as for a drill, so that we should have been in a position to take immediate advantage of any break in the clouds, discretion being of course exercised in altering the uniformity of the intervals between the plates, in order to take advantage of any passing gleam of clear sunshine. Fortunately it was fine and this precaution was not required, but I am sure that it was the only way of making certain of being ready at a moment's notice had the sky been cloudy.

*Operations on the Day of the Transit.*—After the cloudy weather of the previous two days, it was an agreeable surprise when we awoke on the morning of the Transit to find an almost cloudless sky. All preparations had been completed the night before and we were in our places betimes. As the first contact had been computed to occur at about 7h. 13m. 7s. (mean time) the order for commencing the preparation of the plates was given about 7 o'clock, and the work of the day commenced with the exposure of a Janssen plate for trial of the apparatus. After

this two six-inch plates were exposed and then, about bisection, another Janssen, followed by two more six-inch plates and then a third Janssen for the first internal contact, for the exposure of which a signal was to be given by Colonel Tennant. Owing to the wet plate prepared for this having slipped off the dipper, a dry plate was substituted and the plate was mounted in ample time. While watching the image carefully through the red glass, waiting for Colonel Tennant's signal, I noticed that the planet appeared to have passed well within the boundary of the solar disc, though still attached to the limb by a well and strongly defined ligament, so that the planet and ligament were of a distinct gourd-shape exactly like the appearance of the "black drop" one had been led to expect.* On development the plate showed no sign of any such such gourd-like appearance, except at the 21st picture where the clock-work had dragged, and there an image appeared, the exact counterpart of what I had seen.

After this the regular work with the six-inch plates commenced and went on pretty regularly, at the stated intervals of two minutes between each exposure, till about half-past 9, when there was a break of 15 minutes for refreshment and to change the chronograph paper, &c.

Though this break may appear long, it had been found more convenient to have one long break than two or three shorter ones, on account of the loss of time in stopping and getting under way again. It was arranged that the break should take place either well before or after mid-transit, so as to be sure of pictures being taken about the time of mid-transit.

It was also arranged that when the signal for the break was given, all wet plates under preparation should be exposed and dry plates sent in till all the wet plates had been developed and every thing was ready for opening out the doors. In the same manner after the break, dry plates were sent in until the wet plates were ready. The work then went on as before till the time came for mounting the Janssen for the second internal contact, which was exposed by signal from Colonel Tennant. Two more six-inch plates were then taken, then a Janssen, followed by two more six-inch plates, and last of all a Janssen, about the time of last contact, which was exposed and closed a few seconds before the final contact, thus concluding the work.

The sequence of the plates in the racks was examined and the plates were left to dry till next day and then replaced in the plate boxes.

It had originally been intended that 120 six-inch plates should be taken, as it had been found quite possible to do so at the rehearsals, but as I was perfectly dependent on Colonel Tennant's signals for starting the Janssen plates, I allowed plenty of time so as to make sure of having the

* Colonel Tennant remarks with reference to this—"There is no doubt in my mind that the outer part of the sun is *never* free from the result of outstanding astigmatism. For Janssen plates it should have been specially cared for at the expense of the central portion of the picture."

Janssen plates ready when required, without hurry ; and so only two plates were taken between the Janssens instead of four, as had been arranged.

The result of the day's work was 109 six-inch plates taken, but of these two failed entirely, so that only 107 can be counted. These are all fairly clean and free from fog or stains but in many of the plates the images are not so sharp as could have been desired. Though the day was fine and cloudless, there was a good deal of haze and I think the want of sharpness is chiefly due to this and other atmospheric conditions, as the same faults were observed for two or three days after the Transit.

Of the Janssen plates there were five which also were, for the most part, clean, good plates, fairly well defined though not perfectly sharp.

Several of the photographs shew marked irradiation round the planet, and a want of sharpness which may be partly due to the atmosphere of the planet, as the limb of the sun is very much sharper. On some of the pictures distinct streamers are visible round the limb of the planet and proceeding from it. I have not seen anything of the kind mentioned as being observed by other parties, and, as the appearance is not visible on all the negatives, it is no doubt a form of photographic irradiation; but, if not, a comparison of the Roorkee negatives with those taken at other places may throw light on the cause of it.

None of the plates were varnished, as it was considered undesirable to varnish plates intended for future measurement, and also to obviate any chance of the varnished films cracking when removed to England, as is often the case with negatives taken in this country.

With the exception of the want of sharpness of some of the plates, the operations may be considered quite successful as far as the mere photography is concerned. The arrangements described above and the programme of operations answered admirably and I cannot suggest any improvement. Whether the photographs are sufficiently sharp and perfect in other respects to answer the purpose intended still remains to be seen.

*General Remarks.*—During the course of the preparations a good deal of time had to be devoted to putting some of the instruments into proper working order, in which work I was much assisted by Captain Campbell, who had charge of the operations with the great 36 in. theodolite. Thus for some time, the Janssen plates were found to be fogged and so indistinct as to be almost useless. This was due, partly to reflection of light from the polished surface of the wood-work of the slide and the brass-work of the under surface of the exposing disc, which was partially obviated by covering with dead black varnish all the surfaces capable of reflecting light on to the sensitive plate, and partly to the ruby-red glass fixed in the revolving disc not being perfectly impervious to the actinic rays, but this defect was overcome by substituting a piece of thick ruby-glass for the thin, light-coloured piece originally supplied. Even with these precautions, some white light found

its way on to the plate between the revolving disc and the wooden case, which were at a greater distance apart than appeared necessary, though the entrance of light might have been prevented by fitting the exposing disc with a flange running in a groove cut in the wood-work of the slide or fastened above it. There was also considerable friction about the internal surfaces, which caused a strain on the clock-work and gave a good deal of trouble till the cause had been removed. With the exception of these defects, the slide seemed admirably constructed and adapted for the object in view. It remains, however, to be seen how far this ingenious instrument has answered the expectations of its inventor and those who have adopted it, but if it should be used at the next Transit, it would, I think, be desirable that arrangements should be made for the automatic movement to be continued or distributed at intervals over a much longer period than one minute, as on the present occasion, so that all the phenomena attending the contact may be fully observed and recorded. It is also very desirable that the photographer should not require a skilled observer to watch the time of contact for him. The doing so has a very disturbing effect on a man who is able to make a good observation of contact, and time is also lost in preparing and waiting for a signal.

As far as shewn by the plates obtained at Roorkee the differences between pictures taken a few seconds apart are so slight, and the advance of the planet is so imperceptibly marked, if indeed, there is not sometimes an appearance of retrogression caused by atmospheric tremor, that perhaps little would be lost by taking the pictures at intervals of 4 or 5 seconds instead of at every second.

The mounting of the slide necessitates the alteration of the adjustments of the telescope for taking the six-inch plates, thus stopping all such observations about the critical period and it is therefore most desirable that each operation with the Janssen slide should extend over as long a period as possible. Colonel Tennant tells me that the cusp measures are indefinitely more valuable, if good, than any six-inch plates, which he would *entirely* eliminate. In this case, if it were considered essential that the successive pictures should be taken at intervals of not more than one or two seconds, a second, or even a third, Janssen slide might be provided so that they might be rapidly changed one after the other. If it were feasible to construct the slide so that the plates could easily be changed without removing the whole slide from the camera, it would be better still, as in that case the observations could be carried on at every second or two, and three or four plates exposed in quick succession during five or six minutes about the time of contact, and, if desirable, continued at regular intervals afterwards; but this appears to present considerable mechanical difficulties and an arrangement would be required by which the revolving disc could be at once brought into the proper position

for exposing the successive plates instead of having (as in the present slide) to be reversed through an *entire revolution*, which alone takes nearly half a minute.

The photoheliograph, like all work turned out by Mr. Dallmeyer, was an excellent and perfectly finished instrument, but seemed to me to be scarcely sufficiently firmly mounted for continuous work extending over so many hours, with the constant shaking caused by the insertion and withdrawal of the dark slides, which were much stiffer than they ought to have been. This stiffness of the dark slides was found not to be due to climatic influence, because they did not agree in measurement with the focussing screen which fitted perfectly, and they had to be filed down considerably before they would fit; this defect, due no doubt to an oversight in the maker or to hurry in turning out the instrument, was a serious one, as besides the liability to tremor caused by the frequent alteration of declination, the focus might have been disarranged by the alteration in the thickness of the slides by filing, but there was nothing else to be done under the circumstances.

For my part, speaking merely as a photographer, I should prefer the system adopted by Lord Lindsay and the American parties in which the camera was an immovable fixture and the solar image retained in a constant position by means of a siderostat carefully adjusted to follow the sun. In any case, the slides should be constructed to fit quite easily into their places, and in this respect the dark slides made for the equatorial camera used at Dodabetta for photographing the solar eclipse in 1871, were of a much better pattern than those sent out with the photoheliograph.

Another defect of the photoheliograph was that the hanging counterpoise, placed near the object-glass of the telescope when using the Janssen slide, was found to swing and induce a tremor in the instrument, spoiling the definition of the pictures; it was therefore replaced with a rough, but efficient substitute, in the shape of a canvas bag, the ends of which were filled with shot. This was merely hung over the end of the telescope at the proper balancing point and kept the tube perfectly steady.

As regards the process to be adopted for photographing the Transit of 1882 much will depend on the results obtained by the different methods used in December last as to whether photography can be advantageously employed and, if so, which process is most suitable.

As far as my experience goes, the wet process seems less favourable to perfect sharpness and clearness of the image than the dry, but Colonel Tennant tells me he has lately obtained very superior results by using a pyrogallic acid developer with bromoiodised collodion, in place of the iron development. From experience I have gained in preparing for photographing the recent Eclipse, I believe that great advantages may be obtained by slightly staining the ordinary wet films with orange or red anilin dyes or

by the use of *moist* plates, prepared with bromised or bromoiodised collodion afterwards treated with albumen and glycerine, which I have found very simple to prepare and exceedingly free from all tendency to blurring or irradiation. It is probable, however, that before 1882 the usual modes now in vogue for taking negatives will have been quite superseded by the simpler method of using sensitive emulsions which have only to be poured on to the plates and dried without any further preparation. Great advances have recently been made by Carey Lea, Bolton and others in obtaining such emulsions capable of giving pictures with the same rapidity as the ordinary wet or dry processes and with a perfect freedom from the irradiation or blurring so detrimental in astronomical photography, besides which the perfect simplicity and ease of the operations are a strong recommendation; and I may, I think, safely predict that should photography be used for the next Transit, the emulsion processes will, if not exclusively, be used very extensively; unless, possibly, the superiority of pictures taken on daguerreotype plates or silvered glass films over those on collodion should be incontestably proved or some other better process be discovered meanwhile.

Although the photographic operations connected with the observation of a Transit of Venus present no great difficulties, and are in some respects easier than photographing the total phase of an Eclipse, a great deal of patient careful work is required beforehand to ascertain the best conditions for working with regard to local circumstances, and this the short time at my disposal on the present occasion scarcely allowed me to have, especially as so much time was spent over the dry process, which might, as the event proved, have been well employed in perfecting the wet. It is therefore very desirable that the subject should not be lost sight of between this and the next Transit and that every opportunity should be taken of utilising the experience already gained towards ascertaining the most perfect methods of taking these sun-pictures. It would also be advisable that as many as possible of the observers of the last Transit should also take part in the next.

Although the Transit of 1882 will not be visible in any part of India, much useful preparatory photographic work might be done concurrently with the daily observations of sunspots, now that an instrument is available for taking advantage of the comparatively fine weather enjoyed in this country, particularly at the time of year when the weather in Europe is most unfavourable to such observations; and this would not be the least among the many advantages to Science to be gained by the establishment of a Solar Observatory in this country, which has been so earnestly advocated by Col. Tennant and, it is to be hoped, will soon be an accomplished fact.